EO

PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 7 : G01R 15/24

A1

(11) International Publication Number: WO 00/31551

(43) International Publication Date: 2 June 2000 (02.06.00)

(21) International Application Number: PCT/US99/27258

(22) International Filing Date: 18 November 1999 (18.11.99)

(30) Priority Data: 09/198,557 23 November 1998 (23.11.98) US

(71) Applicant: HONEYWELL INC. [US/US]; Honeywell Plaza, Minneapolis, MN 55408 (US).

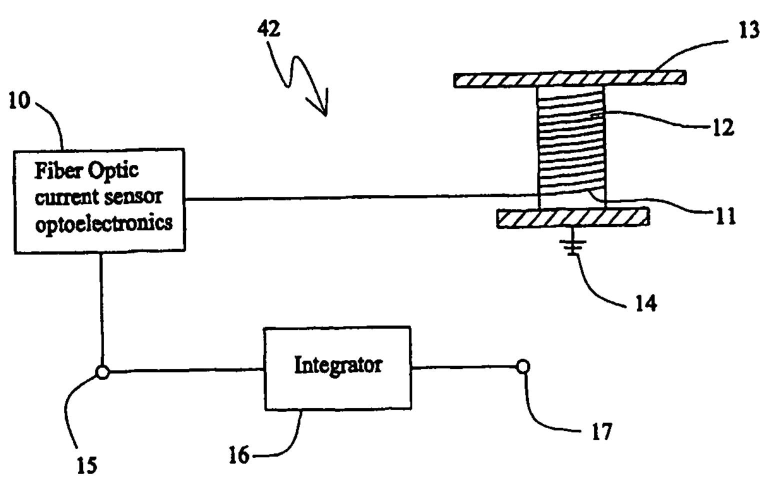
(72) Inventor: BLAKE, James, N.; 5528 East Michelle Drive, Scottsdale, AZ 85254 (US).

(74) Agent: SHUDY, John, G., Jr.; Honeywell Inc., Honeywell Plaza - MN12-8251, P.O. Box 524, Minneapolis, MN 55440-524 (US).

(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published
With international search report.

(54) Title: DISPLACEMENT CURRENT BASED VOLTAGE SENSOR



(57) Abstract

An optical voltage sensor utilizing a Faraday effect based current sensor. The sensor has an optical fiber loop (11) that has light propagating through it. The light has a polarization state or phase that is affected by a displacement current. The displacement current is due to the fiber loop wound on a capacitive standoff (12) that is placed between the voltage to be measured and ground. A photodetector receiving the affected light outputs a signal that indicates displacement current and amounts to a time derivative of the voltage to be measured. The voltage measurement is obtained by integrating the output signal of the detector. The input light to the otpical fiber loop may be modulated with a feedback signal from a signal processor connected to the detector output. The sensor may have a polarimetric or interferometric configuration.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece			TR	Turkey
BG	Bulgaria	HU	Hungary	ML	Mali	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MN	Mongolia	UA	Ukraine
BR	Brazil	IL	Israel	MR	Mauritania	UG	Uganda
BY	Belarus	IS	Iceland	MW	Malawi	US	United States of America
CA	Canada	IT	Italy	MX	Mexico	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NE	Niger	VN	Viet Nam
CG	Congo	KE	Kenya	NL	Netherlands	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NO	Norway	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	NZ	New Zealand		
CM	Cameroon			PL	Poland		
CN	China	KR	Republic of Korea	PT	Portugal		
CU	Cuba	KZ	Kazakstan	RO	Romania		
CZ	Czech Republic	LC	Saint Lucia	RU	Russian Federation		
DE	Germany	LI	Liechtenstein	SD	Sudan		
DK	Denmark	LK	Sri Lanka	SE	Sweden		
EE	Estonia	LR	Liberia	SG	Singapore		

DISPLACEMENT CURRENT BASED VOLTAGE SENSOR

BACKGROUND

The invention pertains to fiber optic sensors and, particularly, to fiber optic voltage sensors.

Over the past decade, fiber optic sensors have received attention in the application of magnetic field sensing and current sensing. Fiber optic current sensors are advantageous over iron-core current transformers, since fiber optic sensors are non-conductive and lightweight. Furthermore, fiber optic sensors also do not exhibit hysteresis and provide a much larger dynamic range and frequency response.

Fiber optic current sensors work on the principle of the Faraday effect. Current flowing in a wire induces a magnetic field, which, through the Faraday effect, rotates the plane of polarization of the light traveling in the optical fiber wound around the current carrying wire. Ampere's law, is stated as

$$I = \oint H \bullet dL$$

where I is the electrical current, H is the magnetic field and the integral is taken over a closed path around the current. If the sensing fiber is wound around the current carrying wire with an integral number of turns, and each point in the sensing fiber has a constant sensitivity to the magnetic field, then the rotation of the plane of polarization of the light in the fiber depends only on the current being carried in the wire and is insensitive to all externally generated magnetic fields such as those caused by currents carried in nearby wires. The angle, $\Delta\phi$, through which the plane of polarization of light rotates in the presence of a magnetic field is given by

$$\Delta\phi = V \int H \bullet dL$$

where V is the Verdet constant of the fiber glass. The sensing optical fiber performs the line integral of the magnetic field along its path, which is proportional to the current in the wire, when that path closes on itself. Thus, one has $\Delta\phi = VNI$, where N is the number of turns of sensing fiber wound around the current carrying wire. The rotation of the state of polarization of the light due to the presence of an electrical current may be measured by injecting light with a well-defined linear polarization state into the sensing region, and then analyzing the polarization state of the light after it exits the sensing region. Alternatively, $\Delta\phi$ represents the excess phase shift encountered by a circularly polarized light wave propagating through the sensing fiber. Sagnac loop

interferometers and the in-line interferometer may be used to detect this excess phase shift.

This technology is related to the in-line optical fiber current sensor as disclosed in U.S. Patent No. 5,644,397 issued July 1, 1997, to inventor James N. Blake and entitled, "Fiber Optic Interferometric Circuit and Magnetic Field Sensor", which is incorporated herein by reference. Optical fiber current sensors are also disclosed in U.S. Patent No. 5,696,858 issued December 9, 1997, to inventor James N. Blake and entitled "Fiber Optics Apparatus and Method for Accurate Current Sensing", which is incorporated herein by reference.

However, a need has arisen for a fiber optic voltage sensor.

SUMMARY OF THE INVENTION

The present invention utilizes the optical circuit of a Faraday effect based fiber optic current sensor. The sensor may be either of the polarimetric or the interferometric (e.g., Sagnac loop and in-line) type. Instead of sensing a real current flowing through the fiber sensing coil, the sensor responds to a displacement current flowing through the fiber sensing coil, which is facilitated by being wound around a capacitive standoff placed between the voltage to be measured and ground. This displacement current is related to the time derivative of the voltage across the sensing coil. The voltage across the sensing coil is obtained by integrating the output of the sensor. The sensing coil may physically extend from ground potential to the wire carrying the voltage to be measured so that the voltage across the sensing coil is the true line to ground voltage.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows an architecture of the current displacement-based fiber optic voltage sensor.

Figure 2 shows the architecture of the fiber optic voltage sensor based on a polarimetric type current sensor.

Figure 3 shows the architecture of the fiber optic voltage sensor based on the in-line type current sensor.

Figure 4 shows the architecture of the fiber optic voltage sensor based on a Sagnac interferometer.

DESCRIPTION OF THE EMBODIMENT

Figure 1 shows in block diagram form a voltage sensor based on a fiber optic current sensor 42. It is a displacement current-based fiber optic voltage sensor. Maxwell's fourth equation in integral form (alternatively denoted the generalized Ampere's law) is given as

$$\oint H \bullet dL = I + \frac{\partial \Phi_E}{\partial t}$$

where Φ_E is the electric flux passing through the closed loop defined by the left-hand side of this equation. This equation may alternatively be written as

$$\oint H \bullet dL = I + C\frac{dV}{dt}$$

where C is the capacitance across the fiber sensor coil 11, V is the voltage on a high voltage line 13, and $C\frac{dV}{dt}$ is the displacement current flowing through a sensing coil 11. In the absence of any real current (I) flowing through the sensing coil 11, this equation reduces to

$$\oint H \bullet dL = C\frac{dV}{dt}$$

From this equation, it can be seen that the output of any Faraday effect based fiber optic current sensor so configured is proportional to the displacement current flowing through sensing coil 11. The displacement current flowing through sensing coil 11 is the changing electric flux passing through sensing coil 11. The displacement current is proportional to the time derivative of the voltage on the high voltage line 13. Passing displacement current output 15 through an integrator 16 results in a voltage output 17 proportional to the a.c. component of the voltage on high voltage line 13.

Fiber sensing coil 11 is wound around a capacitive standoff 12 that is connected to a ground potential 14 on one side and high voltage line 13 on the other. Capacitive standoff 12 advantageously comprises a cylindrical structure made of a high dielectric material. It may also comprise a capacitive divider construction so as to increase the value of the displacement current flowing through there by increasing its effective capacitance. This condition assures that displacement current flowing through the fiber sensing coil 11 is generated by the voltage on high voltage line 13 that is referenced to ground 14.

Figure 2 shows a specific implementation 46 of the fiber voltage sensor of figure 1. Fiber optic current sensor 46 is a polarimetric type. Light from light source 20 passes through linear polarizer 21 to fiber sensing coil 11. Fiber sensing coil 11 is wound around capacitive standoff 12 and extends from ground 14 to high voltage line 13. Fiber sensing coil 11 may be constructed using annealed, spun, twisted, or helically wrapped fiber. After passing through fiber sensing coil 11, the light passes through an analyzer 22 (which is effectively a linear polarizer) to a photodetector 23. The displacement current flowing through fiber sensing coil 11 alters the polarization state of the light impinging on analyzer 22, thus varying the intensity of the light falling on photodetector 23. The output of photodetector 23 is processed by an AC/DC (i.e., the AC component of the light intensity falling on photodetector 23 is normalized by the DC component of the light intensity falling on photodetector 23) signal processor 24 to yield displacement current output 15. This signal is then passed through integrator 16 to yield voltage output 17.

Figure 3 shows a voltage sensor 47 based on the in-line fiber optic current sensor. Light source 20 emits a broadband light that goes through coupler 30 and into polarizer 31 where it is linearly polarized. The linearly polarized light then is split evenly into two waves in the two axes of a birefringence modulator 33 via a 45-degree splice 32. Birefringence modulator 33 may include a fiber optic pigtail on either or both its input and output. Birefringence modulator 33 acts to dynamically vary the phase between the light traveling in its two polarization axes by affecting the indices of refraction in the two principal axes relative to each other in a light medium of birefringence modulator 33. It may be constructed using integrated optics or a piezoelectric modulator. The light then propagates down a polarization maintaining fiber delay line 34 towards a quarter-waveplate 35. Quarter-waveplate 35 may be constructed from a short section of long beat length of polarization maintaining fiber, having a quarter of a polarization beat length or an odd multiple of such quarter beat lengths. Quarter-waveplate 35 converts the two linear polarization states of the light in the polarization maintaining fiber medium into two circular polarization states. The light in these two circular polarization states traverse sensing coil 11, approximately maintaining their state of polarization throughout the coil. The coil may comprise one or many turns of optical fiber. This sensing coil fiber may be made of annealed, twisted, or spun fiber. Alternatively, the sensing fiber may be made using ordinary single-mode fiber wrapped in a helical fashion around a toroid. Fiber sensing coil 11

ends in a reflecting termination 36. Termination 36 causes the circular polarization of light for both polarizations to be reversed upon reflection. Reflecting termination 36 is advantageously co-located with quarter waveplate 35 to provide a well-closed path for the sensing region. The sensing fiber is advantageously wound around capacitive standoff 12 that extends from ground potential 14 to high voltage line 13. It is further advantageously constructed such that the fiber is wound using an even number of layers and uniformly distributed along capacitive standoff 12. This ensures that reflective termination 36 may be co-located with quarter waveplate 35, and that the fiber uniformly senses the electric flux all along capacitive standoff 12.

Upon hitting reflective termination 36, the light retraces its way through the optical circuit, including fiber sensing coil 11, quarter-waveplate 35, delay line 34, birefringence modulator 33, splice 32, polarizer 31 and coupler 30, arriving at photodetector 23. The returning light is converted by quarter-waveplate 35 to linear polarizations, which are likewise reversed from those of the light when it entered waveplate towards reflective termination 36. Since the sense of polarization and the direction of light are reversed for both light waves during their trip through sensing coil 11, the relative phase shift accumulated between them during the first pass through sensing coil 11 is doubled during the return trip. Constructed in this manner, sensitivity to mechanical or thermal disturbances is greatly reduced, since both light waves travel in the same fiber and are subjected to the same disturbances simultaneously. Because the disturbances are common to both light waves, no differential phase shift is induced. An electrical signal, representative of the light impinging photodetector 23 and indicative of the displacement current, is generated in photodetector 23, and is processed in signal processor 37 to yield a signal 15 representative of the displacement current, flowing through fiber sensing coil 11. Displacement current output 15, which is proportional to the time derivative of the voltage between line 13 and ground 14, of signal processor 37 is integrated by integrator 16 to yield voltage output 17.

Signal processor 37 may provide a feedback signal 38 to birefringence modulator 33 (indicated by the dashed line) in order to close the loop of system 47. Feedback signal 38 may be a triangular type waveform (dual ramp) or a serrodyne type waveform. Either of these waveforms may take a digital form as of a digital phase step. Integrator 16 may be imbedded in signal processor 37. Voltage output 17 from integrator 16 may be a digital representation of the voltage on high voltage line 13.

Figure 4 shows a voltage sensor 48 based on a Sagnac interferometer type current sensor. Light source 20 emits broadband light that goes through coupler 30 and into multifunction integrated optics chip 40 where it is linearly polarized and split into two beams which eventually counter-propagate in fiber sensing coil 11. The light beams may also be phase modulated in chip 40. These two light beams or waves propagate down polarization maintaining fibers 41 and 41' towards quarter waveplates 35 and 35', respectively. Quarter waveplates 35 and 35' convert the two linearly polarized light waves into two circularly polarized light waves. These light waves then traverse fiber sensing coil 11 in opposite directions approximately maintaining their circular state of polarization throughout coil 11. Fiber sensing coil 11 may comprise one or many turns of optical fiber. This sensing fiber may be made of annealed, twisted, or spun fiber. Alternatively, the sensing fiber of coil 11 may be made using ordinary single-mode fiber wrapped in a helical fashion around a toroid. The displacement current as the result of the voltage difference between line 13 and ground 14, causes a change in phase relationship between counter-propagating waves. After traversing fiber sensing coil 11, the counter-propagating light waves pass back through quarter waveplates 35 and 35' where they are converted back to linear states of polarization. The two light waves return through polarization maintaining fibers 41 and 41', through multifunction integrated optics chip 40, to coupler 30 and onto photodetector 23. Quarter waveplates 35 and 35' are advantageously co-located to provide a well-closed path for the sensing region of coil 11. The sensing fiber is advantageously wound around capacitive standoff 12 that extends from ground potential 14 to high voltage line 13. Coil 11 is further advantageously constructed such that the fiber is wound using an even number of layers and uniformly distributed along capacitive standoff 12.

The returning light waves to photodetector 23 have a phase relationship that was changed by the displacement current. The resultant phase relationship determines the intensity of the resultant light after the interference of the two returning light waves. Photodetector 23 provides an electrical signal that has a magnitude representative of the intensity of the light impinging detector 23. The electrical signal from detector 23 is indicative of the displacement current. The electrical signal is processed in signal processor 37 to yield an output signal 15 representative of the displacement current flowing through fiber sensing coil 11. Displacement current signal 15 from signal

processor 37 is integrated by integrator 16 to yield an output signal 17 indicative of the voltage on line 13.

Signal processor 37 may provide a feedback signal 38 to multifunction integrated optics chip 40 (indicated by the dashed line) in order to close the loop of the system. The feedback signal may be a triangular type waveform (dual ramp), a serrodyne type waveform, or a digital phase step type waveform. Integrator 16 may be imbedded in signal processor 37. Voltage output 17 may be a digital representation of the voltage on high voltage line 13.

Alternative constructions of the Sagnac interferometer type of the current displacement based voltage sensor may be implemented. Also, alternative constructions of the in-line interferometer type of the current displacement based voltage sensor may be implemented.

CLAIMS

1. An optical voltage sensor comprising:
means for generating a displacement current indicative of a voltage to be sensed;
means proximate to said means for generating the displacement current;
means for detecting the displacement current, and
means, coupled to said means for detecting the displacement current, for converting the detected displacement current to a voltage indication.

2. The sensor of claim 1, wherein said means for detecting displacement current comprises a capacitive standoff situated between the voltage and a zero voltage reference.

3. The sensor of claim 2, wherein said means for detecting displacement current is a fiber optic current sensor.

4. The sensor of claim 3, wherein displacement current has a magnetic field that causes a change in polarization of light in said fiber optic current sensor.

5. The sensor of claim 4, wherein the change of the polarization of light is indicative of the detected displacement current.

6. The sensor of claim 5, wherein said means for converting the detected displacement current into a voltage measurement, integrates the detected displacement current into the voltage indication.

7. The sensor of claim 3, wherein displacement current has a magnetic field that causes a change in phase of light in said fiber optic current sensor.

8. The sensor of claim 7, wherein the change of phase of light is indicative of the detected displacement current.

9. The sensor of claim 8, wherein said means for converting the detected displacement current into a voltage measurement, integrates the detected displacement current into the voltage indication.

10. An optical voltage sensor comprising:
a displacement current generator situated proximate to a voltage to be measured;
a displacement current detector coupled to said displacement current generator; and
a displacement current-to-voltage indication converter connected to said displacement current detector.

11. The sensor of claim 10, wherein said displacement current detector comprises a capacitive standoff situated between the voltage and a zero voltage reference.

12. The sensor of claim 11, wherein said displacement current detector is a fiber optic current sensor.

13. The sensor of claim 12, wherein displacement current has a magnetic field that causes a change in polarization of light in said fiber optic current sensor.

14. The sensor of claim 13, wherein the change of the polarization of light is indicative of detected displacement current.

15. The sensor of claim 14, wherein said displacement current-to-voltage indication converter is an integrator.

16. The sensor of claim 12, wherein displacement current has a magnetic field that causes a change in phase of light in said fiber optic current sensor.

17. The sensor of claim 16, wherein the change in phase of light is indicative of detected displacement current.

18. The sensor of claim 17, wherein said displacement current-to-voltage indication converter is an integrator.

19. A fiber optic voltage sensor comprising:
a light source;
a polarizer coupled to said light source;
an optical fiber coil, connected to said first polarizer, situated proximate to a voltage to be sensed;
an analyzer connected to said optical fiber coil;
a detector connected to said analyzer; and
an integrator connected to said detector.

20. The sensor of claim 19, wherein said optical fiber coil senses displacement current caused by the voltage to be sensed.

21. The sensor of claim 20, further comprising a capacitive standoff situated between the voltage to be sensed and a zero voltage reference, and proximate to said optical fiber coil.

22. The sensor of claim 21, wherein said optical fiber coil is wound around said capacitive standoff.

23. The sensor of claim 22, wherein:
an output from said detector is an indication of displacement current; and
an integrating of the output from said detector provides an indication of the voltage.

24. A fiber optic voltage sensor comprising:
a light source;
a polarizer coupled to said light source;
a polarization maintaining fiber connected to said polarizer;
a polarization mode converter connected to said polarization maintaining fiber;
an optical fiber coil situated proximate to a voltage to be sensed having a first end connected to said polarization mode converter;
a reflective termination connected to a second end of said optical fiber coil;
a detector coupled to said polarizer;

an integrator connected to said detector.

25. The sensor of claim 24, wherein said optical fiber coil can sense displacement current caused by the voltage to be sensed.

26. The sensor of claim 25, further comprising a capacitive standoff situated between the voltage to be sensed and a zero voltage reference, and proximate to said optical fiber coil.

27. The sensor of claim 26, wherein said optical fiber coil is wound around said capacitive standoff.

28. The sensor of claim 26, wherein:

an output from said detector is an indication of displacement current; and

an integrating of the output from said detector provides an indication of the voltage to be sensed.

29. The sensor of claim 28, wherein said polarization maintaining fiber and said polarizer have a connection with about a 45 degree alignment between birefringent axes of said polarization maintaining fiber and said polarizer.

30. The sensor of claim 29, further comprising a modulator connected in between the connection with about a 45-degree splice, and said polarization maintaining fiber.

31. The sensor of claim 30, wherein said polarization maintaining fiber is a delay line.

32. The sensor of claim 31, further comprising:

a signal processor connected to said detector; and

a closed-loop feedback connection from said signal processor to said modulator.

33. The sensor of claim 32, wherein said modulator is a birefringence modulator.

34. A fiber optic voltage source comprising:

a light source;

a beam splitter coupled to said light source;

an optical fiber loop connected to said beam splitter, wherein a portion of said optical fiber loop is proximate to a voltage to be sensed;

a polarization mode converter connected within said loop;

a detector coupled to said beam splitter; and

an integrator connected to said detector.

35. The sensor of claim 34, wherein the portion of said optical fiber, proximate to the voltage to be sensed, can sense displacement current caused by the voltage to be sensed.

36. The sensor of claim 35, wherein said beam splitter is for splitting light into two beams that counterpropagate in said optical fiber loop and for combining beams returning from said optical fiber loop.

37. The sensor of claim 36, further comprising a capacitance standoff situated between the voltage to be sensed and a zero voltage reference.

38. The sensor of claim 37, wherein the portion of said optical fiber, proximate to the voltage to be sensed, is wound on said capacitive standoff.

39. The sensor of claim 38, wherein:

an output from said detector is an indication of displacement current; and

an integrating of the output from said detector provides an indication of the voltage to be sensed.

40. The sensor of claim 39, further comprising a modulator coupled to said splitter.

41. The sensor of claim 40, further comprising:

a signal processor connected to said detector; and

a closed-loop feedback connection from said signal processor to said modulator.

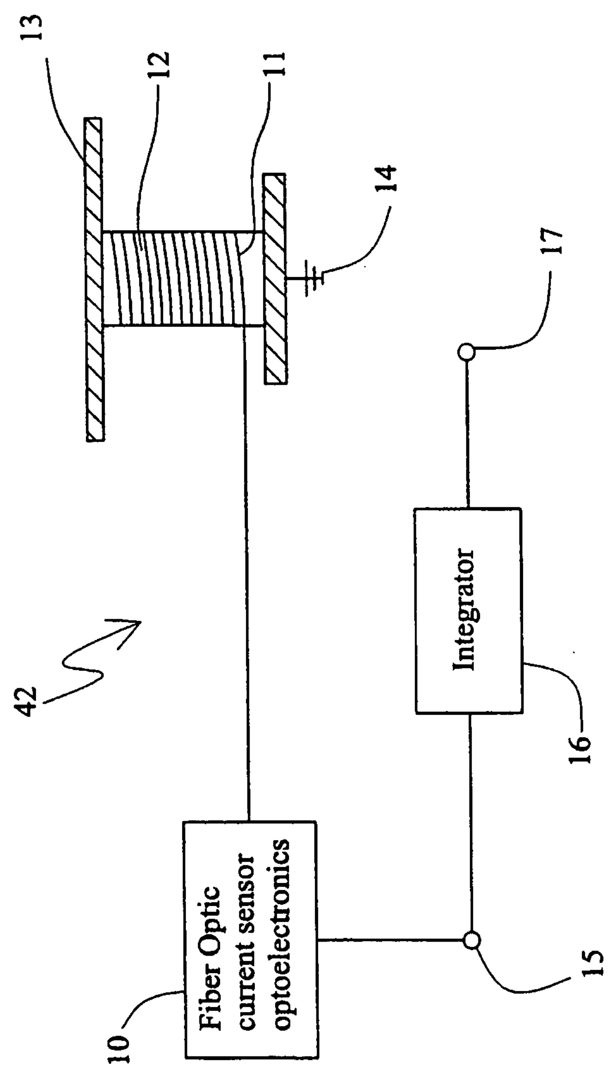

13
12
11
14
17
42
Integrator
16
Fiber Optic
current sensor
optoelectronics
10
15

Fig. 1

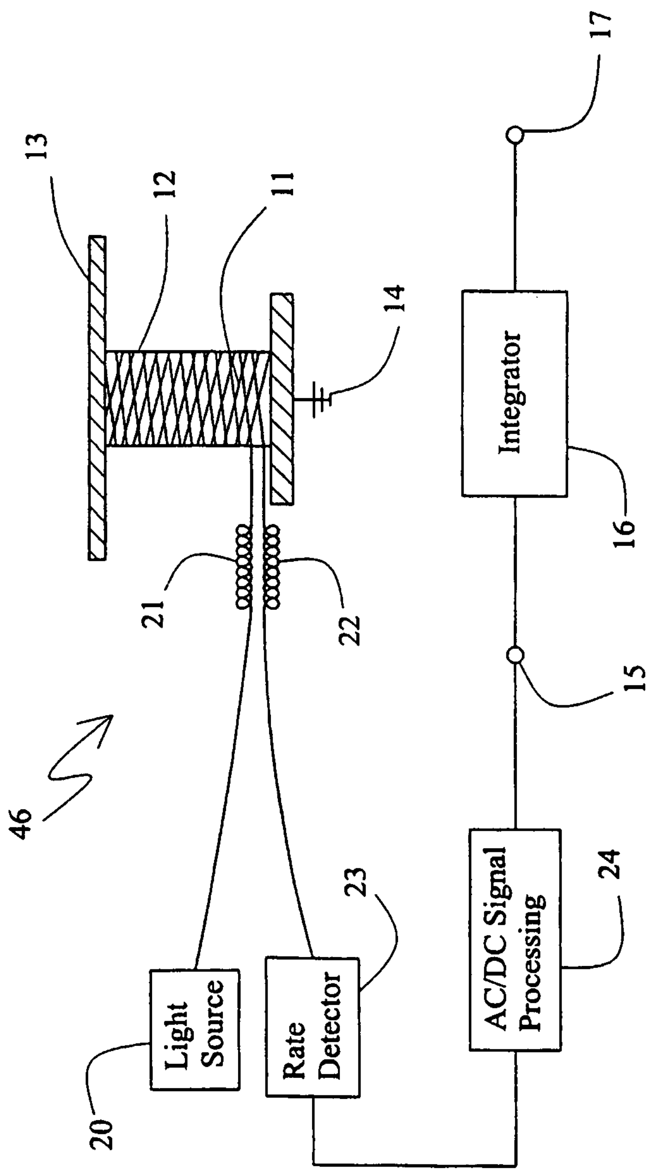

13
12
11
14
17
Integrator
16
21
22
15
46
23
24
AC/DC Signal Processing
Light Source
Rate Detector
20

Fig. 2

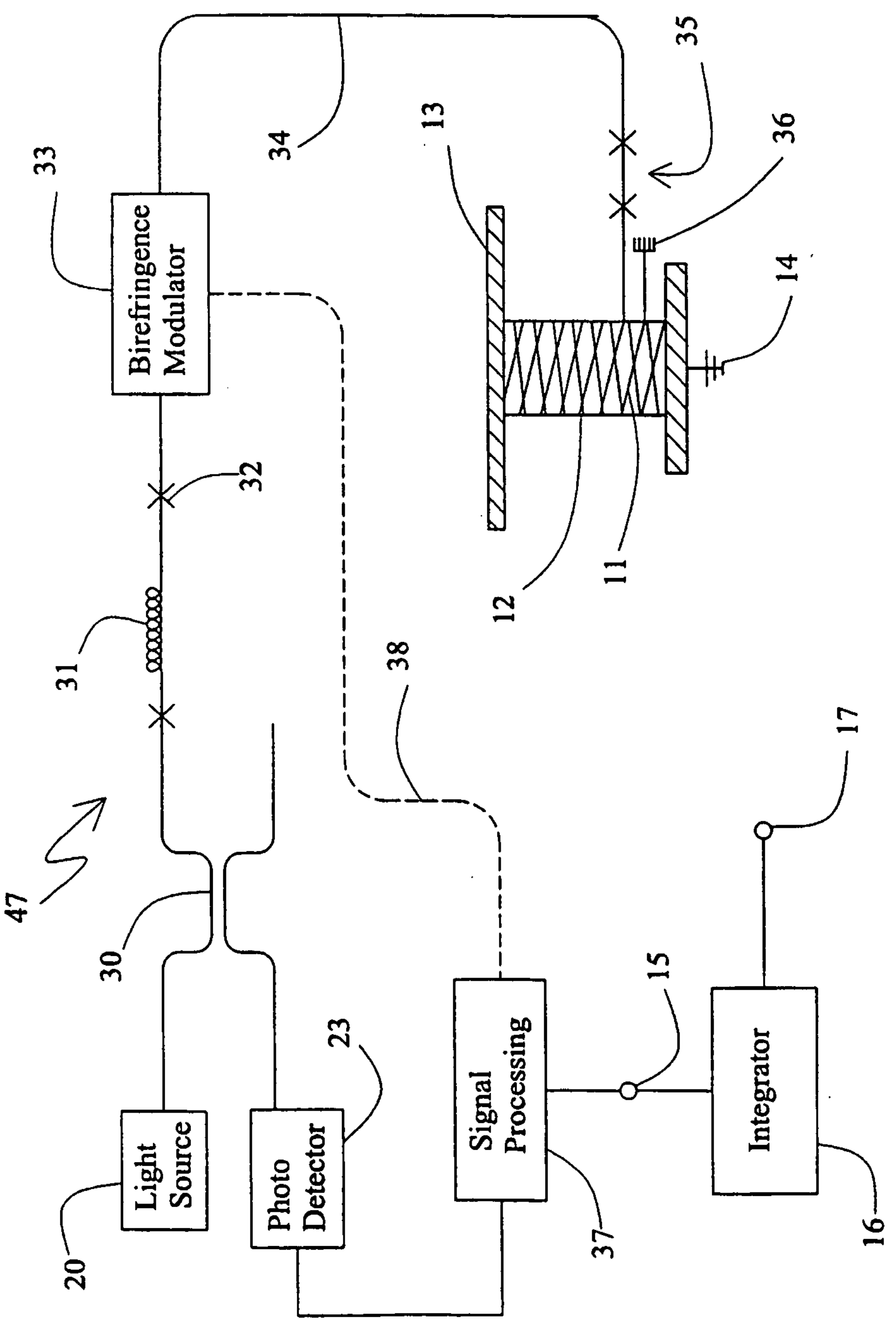

Light Source
Photo Detector
Signal Processing
Integrator
Birefringence Modulator
11
12
13
14
15
16
17
20
23
30
31
32
33
34
35
36
37
38
47

Fig. 3

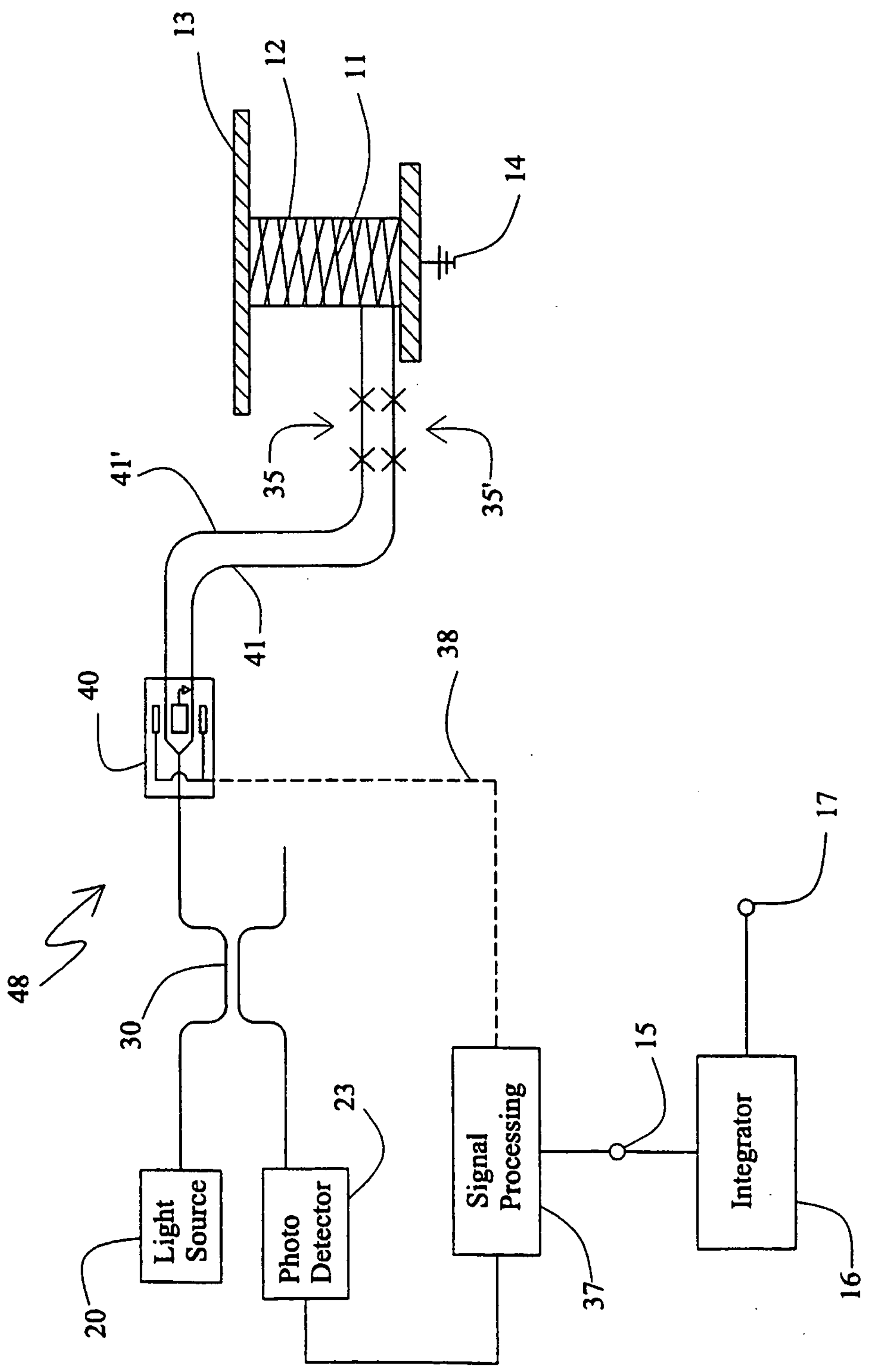

13
12
11
14
35
35'
41'
41
40
38
48
30
17
15
Light Source
20
Photo Detector
23
Signal Processing
37
Integrator
16

Fig. 4

INTERNATIONAL SEARCH REPORT

Inte onal Application No
PCT/US 99/27258

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G01R15/24

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G01R

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 156 533 A (WESTINGHOUSE ELECTRIC CORP) 2 October 1985 (1985-10-02) abstract; figures 1-5,7 page 4, line 11 - line 12 page 5, line 7 - line 11; table 1 page 6, line 7 - line 8 page 8, line 10 - line 24 page 9, line 30 -page 10, line 3	1,2,10, 11
Y		3-9, 12-40

	-/--	

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
15 February 2000	25/02/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Fritz, S

1

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 99/27258

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
X	CEASE T W ET AL: "OPTICAL VOLTAGE AND CURRENT SENSORS USED IN A REVENUE METERING SYSTEM" IEEE TRANSACTIONS ON POWER DELIVERY,US,IEEE INC. NEW YORK, vol. 6, no. 4, 1991, page 1374-1379 XP000271640 ISSN: 0885-8977 abstract; figures 1,4	1,2,10, 11
Y	WO 97 01100 A (ASEA BROWN BOVERI ;UNIV SYDNEY (AU); BJARME MARGARETA (SE); BASSET) 9 January 1997 (1997-01-09) abstract; claim 1; figure 1 page 1, line 17 -page 2, line 3 page 3, line 34 -page 4, line 5	3-9, 12-40
A	EP 0 806 675 A (SCHNEIDER ELECTRIC SA) 12 November 1997 (1997-11-12) abstract; figure 4	1-40
A	BOHNERT K ET AL: "INHERENT TEMPERATURE COMPENSATION OF A DUAL-MODE FIBER VOLTAGE SENSOR WITH COHERENCE-TUNED INTERROGATION" JOURNAL OF LIGHTWAVE TECHNOLOGY,US,IEEE. NEW YORK, vol. 16, no. 4, April 1998 (1998-04), page 598-604 XP000768965 ISSN: 0733-8724 abstract; figure 1	1-40
A	FR 2 209 937 A (SIEMENS AG) 5 July 1974 (1974-07-05) claims 4,5,7,14,21-23; figures 7-12	1,10,19, 24
A	CH 459 359 A (MERLIN & GERIN) 1968 claim; figure 3	1,10,19, 24
A	US 5 644 397 A (BLAKE JAMES N) 1 July 1997 (1997-07-01) cited in the application the whole document	24, 30-34, 40,41
A	US 5 696 858 A (BLAKE JAMES N) 9 December 1997 (1997-12-09) cited in the application the whole document	24,30, 34,40,41
X	DE 37 27 950 A (JORDAN GMBH GEORG) 10 March 1988 (1988-03-10) abstract; figure 4	1,10

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 99/27258

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
EP 0156533	A	02-10-1985	US	4578639	A	25-03-1986
			AU	578268	B	20-10-1988
			AU	3918785	A	05-09-1985
			BR	8501028	A	29-10-1985
			CA	1220820	A	21-04-1987
			ES	540819	A	01-06-1986
			JP	60205375	A	16-10-1985
			MX	158463	A	02-02-1989
			ZA	8501197	A	30-10-1985
WO 9701100	A	09-01-1997	AU	6247196	A	22-01-1997
			CA	2221457	A	09-01-1997
			EP	0834078	A	08-04-1998
			JP	11508361	T	21-07-1999
EP 0806675	A	12-11-1997	FR	2748570	A	14-11-1997
			JP	11002648	A	06-01-1999
			US	5936395	A	10-08-1999
FR 2209937	A	05-07-1974	DE	2261151	A	27-06-1974
			BE	808503	A	29-03-1974
			CH	571225	A	31-12-1975
			JP	49090973	A	30-08-1974
			US	3936742	A	03-02-1976
CH 459359	A		BE	694196	A	31-07-1967
			DE	1591975	A	14-01-1971
			FR	1432677	A	08-06-1966
			GB	1139271	A	
			NL	6702666	A	18-09-1967
			SE	326494	B	27-07-1970
			US	3502978	A	24-03-1970
US 5644397	A	01-07-1997	NONE			
US 5696858	A	09-12-1997	AU	3826197	A	06-03-1998
			CA	2262640	A	26-02-1998
			CN	1229475	A	22-09-1999
			EP	0916098	A	19-05-1999
			WO	9808105	A	26-02-1998
			US	5987195	A	16-11-1999
DE 3727950	A	10-03-1988	NONE			